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ABSTRACT

A study examined the language and interactions that occurred in classes where teachers felt they were providing an environment that fostered reasoning about their coursework. The discourse within the diverse classrooms of eight high school teachers (two each in American literature, American history, biology, and physics) was examined. In each discipline, the teachers' instructional styles differed, with one placing more emphasis on the content and the other on the students' ways of thinking about that content. Results indicated that: (1) reasoning was taught and learned in academic classes; (2) such reasoning was subject-specific and embedded in the pragmatic routines of subject-driven lessons; (3) the specifications of such reasoning were implicit and therefore unavailable for overt use in lesson planning or as strategic knowledge to be taught; (4) this kind of discipline-specific reasoning may or may not be sufficient for successful participation in disciplinary learning; and (5) certain types of pedagogical approaches or styles may inhibit or support such discipline-appropriate thinking. Findings suggest the need for additional studies involving more teachers before explicit suggestions for the recasting of instruction along discipline-specific lines can be made. The categories identified may provide a useful place to start an investigation leading toward productive instructional reform. (Two tables of data are included; 39 references are attached.) (RS)

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Judith A. Langer
Carla Confer
Mary Sawyer

National Research Center on
Literature Teaching & Learning
UNIVERSITY AT ALBANY • SUNY

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School of Education • 1400 Washington Avenue • Albany, New York 12222

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Judith A. Langer
Carla Confer
Mary Sawyer

National Research Center on Literature Teaching and Learning
University at Albany
State University of New York
1400 Washington Avenue, Albany, New York 12222

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Teaching Disciplinary Thinking in Academic Coursework

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In a series of studies, Langer has been addressing the hypothesis that a variety of current problems in American education stem from an unrealistically narrow conceptualization of the nature of academic learning--one that fails to take the uniquely discipline-specific ways of reasoning into account. These studies grow from the assumption that there are two components of academic learning in each discipline, one having to do with particular content knowledge, the other having to do with ways of knowing and reasoning that are accepted as appropriate and necessary for learning and understanding within the particular field. In the context of reasoned thought, for example, this means that in addition to deriving a surface understanding of information, students must learn to understand the ways in which evidence is presented and arguments are developed in the texts they read and write for particular subjects. Comprehending subject area reading material goes beyond understanding the content, and includes the ability to construe and critique the information in appropriate ways. So too, writing about the content requires a reasoned understanding of the material and also a knowledge of ways to present the information that is appropriate to that particular discipline. That the content differs from discipline to discipline is obvious and trivial; our understanding of the ways of knowing embedded within each discipline is less clear. There is a long tradition in American education of granting equivalent "mental discipline" to all academic subjects, as well as of teaching generic modes of argument and exposition as part of the curriculum in English. At the same time, the philosophy of each school subject has usually stressed its unique value to culture and society--the value of "historical perspective," "scientific objectivity," or "literary sensitivity," for example.

One study (Langer & Applebee, 1988; Langer, 1992b), traced these conflicting views in the history and philosophy of several disciplines, testing the argument that the lack of a clear conception of what is unique and what is generic has led to an overemphasis on particular content (where the uniqueness of each discipline is clear and easily assessed), and a paucity of attention to ways of thinking and knowing (which we have failed to articulate clearly or to implement well in any subject). It then looked at the conceptions of academic learning held by specialists in particular disciplines, including a spectrum of university and high school teachers. The focus was on their general view of what counts as important in their subject, as well as on the ways in which they were able to articulate the features of that knowledge. To provide a manageable universe of study, the project team focused on three subject areas: American literature, American history, and biology. This allowed examination of the extent to which teachers in different disciplines emphasize different rules of evidence and procedure--that is, the extent to which they reflect

discipline-specific ways of knowing and reasoning in their teaching. Findings from this study suggest the following:

1. Each of the disciplines has increasingly focused on the tentative nature of "truth," leading to an emphasis on the need for more active questioning and interpreting rather than on simple accumulation of facts.

2. The shift from stable "truths" to conditional knowledge found in the disciplinary literature is often paralleled in educational theory, but has not necessarily made its way into the teaching journals.

3. All teachers in the study wanted their students to think. However, they more often talked about such issues when discussing abstract goals, and more likely focused on specific content when talking about the day to day details of teaching and learning.

Findings also suggested that although ways of thinking are a central concern to each community, there seems to be a gradual shift in priorities. The "pure" disciplines' belief in the instability of knowledge and the need for inquiry are replaced in the schools with a focus on stable content and less inquiry. Further, teachers do not seem to have a "codified" language to talk about ways of knowing, even when they want to. The closer to the daily activities of the student, the more the focus seemed to turn to facts, to the exclusion of ways to think about them.

However, this study was limited to teacher interview data, which needed to be augmented with classroom observation. The follow-up study discussed in this chapter took the next step, by observing cross-disciplinary conversations among teachers concerned to explain what they value to one another, and by "living in" classrooms in order to examine the relationships between teachers' expressions of the knowledge and reasoning they value, and their ways of teaching--the pedagogical strategies the teachers adopt as they shape the ways their students read, write, and discuss. The study sought to contribute to a) a rethinking of instruction in terms of ways of knowing and doing within particular content domains; b) a reinterpretation of the goals of particular courses of study in terms of that rethinking; and c) a grounding of the general argument in the detail and complexity of the language and communication of the classroom. It grows from the position that although notions of discipline-specific thinking need not be considered at odds with more general theories about reasoning (but rather as providing specifications for contextualized actualizations), in pedagogical research and practice they are polarized, with little attempt to understand the different approaches to reasoning that underlie the differing academic contexts that students encounter.

Related Studies

In the past few years, a number of studies have reported that American children are not learning to think deeply enough or to deal with issues broadly enough across a wide range of

academic subjects (e.g., Applebee, Langer, & Mullis, 1989; Applebee, Langer, Mullis, Jenkins, & Foertsch, 1990; Boyer, 1983; Langer, Applebee, Mullis, & Foertsch, 1990; Mullis & Jenkins, 1988, 1990; National Commission on Excellence in Education, 1983). We find these results troubling. Further, Langer has explored the relationship between the teaching of academic subjects and students' ability to reason about what they read and write in a series of studies with Arthur Applebee (Applebee, Langer, Mullis, Jenkins, & Foertsch, 1984; Langer, 1984; Langer & Applebee, 1987). These studies have examined writing across a variety of academic disciplines and traced the relationships between that writing, the teachers' values, and the types of learning fostered in their classrooms. Though the focus in these studies was on the teaching of writing, the typical writing assignment was in fact a response to assigned reading in textbooks. Thus these studies of writing skills were also studies of students' opportunity to reason about what they had read in their various subject classes. Results indicated that students were rarely challenged to explain their interpretations or encouraged to examine the evidence on which they had based their conclusions. More typically, in all areas of the curriculum, they were asked to summarize information and points of view that had been presented to them by the teacher or the textbook.

The initial studies attributed such findings to a lack of effective models of alternative approaches to instruction--in particular, they noted the lack of instructional models that stressed the process of thinking about what students had read or learned (even though recent trends in the teaching of both reading and writing have placed great value on such approaches). In response to the need for such models, a series of studies of teachers who used writing after reading in interesting and effective ways, in a variety of academic disciplines, was initiated. Though these studies were planned as a way to develop a series of models of effective instruction, the major outcome was to suggest new ways to conceptualize academic learning.

From these studies, it was learned that if new activities stress one kind of knowledge but teachers have been trained to look for other types of performance as evidence of learning, the new approaches make little difference. Results were consistent across these subject areas (science, history, and English). Most teachers focused upon factual knowledge about a subject, and were relatively successful in insuring that students developed an understanding of their subject at that level; they trained students to comprehend and remember particular facts. At the same time, their students failed to reason about those facts, whether in science, history, or English. Some of the causes are institutional, tied to evaluation systems, public expectations, and conditions of instruction. Others are more directly related to the content of instruction--to what students are asked to learn and what teachers have learned to look for as evidence of that learning. One central problem is that while teachers can easily recognize (and reward) surface understanding and "correct" information, they have more trouble articulating the rules of effective reasoning that govern ways of knowing and doing within their particular disciplines. As a result, their definitions of progress, and of success, are inevitably based on those aspects of learning that they can articulate--the facts or information out of which textbook arguments are presented, rather than the reasoning skills that students need in order to analyze such arguments or to construct new arguments themselves.

A recent series of studies (Langer, 1990; 1991; 1992a) has involved collaboration with a group of English teachers with the goal of developing more thought provoking activities in the

teaching of literature. These studies have shown that these activities occur on a sustained basis only in those situations where the teacher has been able to conceptualize a notion of learning that has at its core the ways in which students think about the course content. However, because this way of viewing the goals of instruction runs counter to most of the traditional materials, tests, and objectives that dominate the school curriculum, it is very difficult for teachers with strong intentions for change to develop a consistent and stable way of viewing, teaching, and talking about ways to think in their subjects. Thus, if teachers are to help students reason when they read, write, and talk about their coursework, then university-based and teacher researchers must begin by engaging in collaborative studies to articulate the ways of knowing and reasoning--of how to know and talk about "what counts" as central to their courses. Only then can we begin to help teachers develop new and consistent ways to evaluate student learning in terms of higher-level reasoning rather than in terms of surface understanding of particular content. (For a discussion of these distinctions see, for example, Vygotsky's notions of pseudoconcepts: Vygotsky, 1962; Rieber & Carton, 1987; Wertsch & Stone, 1985).

It is worth contrasting this point of view with traditional notions of content area reading and writing (see Langer & Allington, 1992). For example, in the past, content area reading and writing have been treated as consisting of a variety of generic strategies that teachers should be aware of so that they can help their students understand the content and learn to deal with difficult text. They have been seen as part of "skills" instruction, often within the domain of English or reading teachers who taught generic reading, writing, and study skills. If transferred to the content area classroom, such instruction was seen as part of the teaching of reading and writing skills, not as a central part of the subject area curriculum.

In contrast, the rationale motivating this work is that a focus on reading, writing, and reasoning in the content classroom is (or should be) central to the contemplation of the subject area itself. This notion of socially-based academic learning is at the root of a sociocognitive view of learning (see Langer, 1987; Scribner & Cole, 1981; Vygotsky, 1962) which holds that cognitive behaviors are influenced by context and effect the approaches toward knowing as well as the meanings that learners produce. It is these approaches toward knowing, rather than generic reading and writing strategies, that are seen as central to academic learning and reasoning.

The validity of this argument depends, in part, on the level of analysis that one adopts. Previous studies have made it clear that there are broad strategies of argument or uses of language that are common to the various high school subjects (Applebee, 1984; Britton, Burgess, Martin, McLeod, & Rosen, 1975; Calfee & Curley, 1984; Langer & Applebee, 1987). Students of literature, of history, and of science write reports about specific events, for example, and also read and write analyses of such events. These strategies capture consistencies across varied contexts of language use. At the same time, however, the similarity in underlying purpose may be masking very important differences in the ways in which these purposes are achieved. These differences are likely to involve very fundamental concepts--notions of causality and proof, of evidence or warrants for claims, of assumptions that can be taken for granted, and of premises that must be made explicit and defended. Such concepts may lie at the heart of successful understanding of a new discipline, as well as at the heart of the development of the reasoning abilities that so few students seem to achieve.

Langer's (Langer, 1992b) studies of effective teachers of English, science, and history have highlighted the extent to which schools and textbooks treat reading and writing as a way to present particular content (often codified in elaborate scope and sequence charts) rather than as an introduction to new ways of knowing and doing. It is this content that drives their curriculum and that is reflected in the class, school, and district examinations that students face.

There is another way to view the classroom, however, that transforms the nature of the reading and writing activities that occur. This is to view the classroom as a community of scholars (or scholars and apprentices) with its own public forums with associated rules of evidence and procedures for carrying the discussion forward. (See, for example, Anderson et al, 1990; Bazerman, 1981; Bizzell, 1982; Faigley & Hansen, 1985; Herrington, 1985; McCarthy, 1987). Students must learn, then, not only the "basic facts" around which texts are structured, but the legal and illegal ways in which these facts can be mustered in the forum defined by that classroom. The forum will be partly oral, in the presentations and discussions that make up the dialogue of instruction, and partly written, in the materials students read and papers they write. The quality of the reading material and the nature of the teacher's questions, assignments, and interactions are important, since these will provide the most extensive models of what counts as effective discourse and reasoning. Reading, writing, and discussion become vehicles for learning the ways of organizing and presenting ideas that are most appropriate to a particular discipline. In such a view, the development of literate thought (see Langer, 1987) becomes a major agenda of instruction in all of the academic disciplines.

This is a sociocognitive view of both literacy and instruction. What evidence is there for it? A variety of scholars have put forth related arguments, developing them in the context of an examination of the conceptual, intellectual, or social traditions of a given disciplinary community (Bazerman, 1981, 1982; Bizzell, 1982; Kuhn, 1962; Odell, 1980; Roland, 1982; Toulmin, 1958, 1972). Herrington (1985) complements this theoretical work by studying the nature of such disciplinary communities (or forums) at the college level. Basing her conclusions on lengthy ethnographies of two chemical engineering classes, she found that even within the specialized context represented by this subject-matter, the characteristics of the "forums" in the two classes were very different. Students were learning not only the specific content of chemical engineering, but also the specific types of claims and warrants that were construed as appropriate in particular contexts. Success in these classes, then, depended in part upon learning highly specific strategies and routines for evaluating and judging what they read, routines that were inextricably linked with the particular content under study. McCarthy (1987), in related work, studied the various writing and thinking experiences of an undergraduate student as he moved from course to course, describing the different ways of communicating and concerns for knowing that characterized the courses. In yet another study, Berkenkotter, Huckin, & Ackerman (1988) traced the socialization of a first year graduate student into the particular rhetorical and intellectual traditions represented by a doctoral program in rhetoric and composition. All three of these studies highlight the discipline-specific as well as the community- or classroom-speci fic nature of the particular reasoning strategies which students must develop. In a very different tradition, Applebee, Durst, and Newell (1984) analyzed the structure of published texts, and student writing in high school science and social studies. Using a variety of text-analytic procedures, this study found not only that the texts produced by students and published writers

differed in consistent ways, but also that the patterns of these differences were different in the two subject areas. These differences between subjects were particularly clear in the patterns of linguistic features marking causality, time sequence, logical sequence, and the like--the features most likely to reflect differing types of evidence as well as different ways of organizing that evidence to sustain an extended discourse.

Yet, characteristics such as those described in these various studies are rarely articulated by the teachers involved, though there may be an intuitive recognition that such differences exist. If we are to create powerful student-thinkers, we must better understand (and come to articulate) the features of argument and analysis that characterize good thinking in particular disciplines. This will create a focus on ways of knowing and doing, as well as on particular content. To do this will require studies, such as the one reported in this chapter, that seek to describe ways in which teachers' implicit values of discipline-appropriate reasoning are evidenced in subject-matter coursework.

The Study

This study was designed to examine the language and interactions that occurred in classes where teachers felt they were providing an environment that fosters reasoning about their coursework. It focused on the ways in which teachers' conceptions about knowing and concerns for content affected the day to day goals, activities, and interactions in their classes--their students' academic environment for learning. We examined the discourse within the diverse classrooms of 8 high school teachers (2 each in American literature, American history, biology, and physics). All of the teachers had taught from 7 to 31 years, and were considered to be excellent teachers by their department supervisors and colleagues. In each discipline, the teachers' instructional styles differed with one placing more emphasis on the content and the other on the students' ways of thinking about that content. A brief description, by subject area, follows:

Biology

Marge Rhodes teaches biology in an upper middle-class suburban community. To her, biology is an important course for students to take because "students need to know science as adults, especially biology to understand illnesses, disease, reproduction...." She encourages her students to participate in discussion. Marge stands in front to introduce a lesson, then moves around the room to help student groups. Of the two biology teachers we studied, her classroom provides more frequent opportunity for students to express and examine their own ideas.

Gabe Rose is a biology teacher in a middle class suburban community. As to his course goals, he says, " I would like to polish scientific reasoning skills--the uses of control groups, the formulating of hypotheses, the observational skill...." He provides his students with an extensive outline at the beginning of a unit that lists the teacher's plans, labs due, work sheets, exams, etc. He relies on the outline to keep track of what he has covered and the students' progress.

Physics

Stan Canfield is a physics teacher in a high school in a small city. In discussing his views of physics instruction, Stan says, "Students remember what they control and what they do...." He always provides shared experiences (lab demonstrations) as a way to bring the group together to discuss what they've seen. From this, Stan guides them to make links. Of the two physics teachers we studied, Stan invites students to work through their own ideas more often.

Ken Rivers teaches physics in the same high school as Marge. He says, "Physics...[relates] so easily to things within one's own experiences." He carries this out in class, giving his students many examples from everyday life. Ken's lab work interactions are informal, with students working in self-chosen groups and Ken available for questions. His lecture class is more traditional with straight rows of desks, and time is more formal and fast paced than his labs. Ken admits to being teacher-centered ("I'm always uncomfortable when I'm not in charge").

American History

Kenny Craft teaches American History and Government in an inner city school, with approximately half the students belonging to ethnic and racial minority groups. He says, "It is important to develop a love of your country...and an understanding of your fellow man and his behaviors....History can also be a medium for teaching thinking skills...." Although he lectures a good portion of the time, his students are listened to and engaged. He has them discuss, debate, and work on joint projects--communicate.

Laura Barnes teaches U.S. History and Government at a suburban high school. She thinks it is critical for all students to study history. "It's part of our cultural literacy. It leads to understanding of current events... [and]... an appreciation of their past." She uses cooperative learning activities in her class, with small group discussions and collaborative projects. Yet, of the two history teachers, Laura more often directs the instructional interactions.

American Literature

Terry Andrews teaches American Literature at the same high school as Laura. He sees himself as "...striving to help [students] make the connections between what they are reading in class and the values of today...." Terry's class is characterized by student centered activities and student-to-student cooperation; the development of students' ideas and interpretations are the focus of instruction.

Linda Reed teaches American Literature in an urban high school. She feels it is important for students to study literature because "they need it to function effectively in the world, to be informed citizens...." The students keep logs where they write about their own ideas and responses. However, these are at the periphery of class concerns. Linda is often after a particular interpretation, and uses the literature lessons as a time to retrace the piece with her students, from beginning to end.

Table 1
Collaborating Teachers

Subject	Less Traditional	More Traditional
Biology	Marge Rhodes	Gabe Rose
Physics	Stan Canfield	Ken Rivers
Am. History	Kenny Craft	Laura Barnes
Am. Literature	Terry Andrews	Linda Reed

During the year-long project, the teachers, research assistants, and Langer met as a collaborative project team to focus on the similarities and differences within and across classes in goals, activities, and issues that surround students' reasoning and on ways to identify and talk about that thinking in each subject. Each research assistant worked closely with one or two teachers, observing classes, and meeting and interviewing the teachers before and after the lessons to understand better their goals when planning as well as when reflecting back on the lessons. Interviews with teachers focused on their general goals for the course, as well as their planning of particular lessons.

The research assistants and Langer met on a weekly basis for case study sessions. In these meetings we jointly discussed the whole-group meetings, class observations, and interviews, identifying and finding evidence for patterns of concerns as well as communication between and across disciplines.

Findings

Through recursive analyses of the data, we searched for patterns in what the teachers in each field valued as knowing based upon what they said and wrote about their teaching goals and practices as well as in the assignments they gave, the discussions and activities they encouraged, and what they acknowledged as thoughtful in their responses to student papers.

The findings will be discussed in two parts, each focusing on a different aspect of the ways of thinking emphasized and rewarded in the eight classrooms. The first section will examine

how the teachers, in-common ways of talking about reasoning--in particular their shared valuing of making connections and asking good questions--play themselves out in the different subject areas. In general, these analyses will conclude that the shared vocabulary masks real differences in what counts as knowing and reasoning in different subjects. The second section will examine the pedagogical strategies that teachers use to shape their interactions with students, and through which they model and scaffold appropriate ways of thinking in their disciplines. In this section, one set of interactive strategies (finding common ground in discussing new concepts, clarifying what students' know, and focusing on significant detail) are used in very similar ways across the subject areas studied. A second set of concerns reflected in different lesson segments (orienting students' attention, refining their understanding, and helping students select appropriate evidence), however, again play themselves out in ways that are discipline specific. This section will conclude that teachers' tacit knowledge of their discipline leads them to guide students toward ways of thinking appropriate to each discipline. While their teaching styles affected the amount of access the students had to thinking through their own understandings, the discipline-specific nature of the various kinds of thinking was reflected in each of their classrooms.

Discipline-Specific Ways That Teachers Value Students' Thinking: What They Say, Write, and Teach

All of the teachers voiced similar concerns about how students come to know, often using similar words to voice those concerns. Making connections and questioning appeared as two significant themes in the teachers' conceptions of knowing their disciplines; they said and wrote that they wanted their students to learn to make connections and to ask good questions. They also said they wanted their students to analyze, to interpret, to provide evidence, and to predict, but these reasoning behaviors were implicitly treated as necessary components or subsidiaries of connecting and questioning rather than as serving different purposes. Across disciplines, when they explained what they meant, their language was similar (e.g., about connections--"You know, making links, connecting knowledge with new material," and about questions--"Using what they know to learn more."). But when they provided examples, when they discussed student work, and when we observed what they valued in their actual teaching contexts, we soon realized that these terms had different meanings for the different subject areas. Their general language let them talk with us and with one another about the importance of reasoning abilities, but at the same time it masked real but unarticulated differences in the ways of thinking modeled and rewarded in their classes. These latter were evidenced in the subtle but consistent ways in which they supported certain types of sensemaking on the part of their students--ways that were not in conflict with, but rather were discipline-appropriate actualizations of the generalized vocabulary. Their knowledge of discipline-specific ways of knowing was tacit, based in previous experiences within their disciplines rather than in their general educational training.

Across subjects, all teachers said they wanted their students to make connections and ask good questions. But what they meant by this was quite different based on their subject area.

Biology

Connections. When the biology teachers spoke of wanting students to make connections, they were concerned with moving from smaller to larger units of understanding as well as linking terminology to taxonomies. Because biological functions and systems are not readily visible, they felt it was important for their students to learn about the parts of systems and their properties and to make connections among them--as they operate in organisms or function within systems. For example, Gabe focused on physical properties of cells as a way to build toward an understanding of cell division. He said:

> Students need to make connections among the different parts of a plant and animal cells. One is rectangular and the other is square. There needs to be a connection of properties (in this case shape). Then the student needs to connect knowledge of the properties in a way to understand and approach new material (e.g., cell division).

The biology teachers also placed a great emphasis on their students' acquisition of subject-specific vocabulary, stressing conceptual connections between new vocabulary and its meaning within the system being studied. For example, Marge wanted her students to be able to connect their new words with those the students already knew in order to help them understand their meaning (and function) within the reproductive system, their topic of study. She said:

> Like telophase chromosomes are far apart. What's the Greek word for far? Think about telephone and television.

This focus on connecting word meanings results from their conviction that the acquisition of the technical vocabulary is an integral part of concept learning. Almost every lesson introduced new words.

Questions. In talking about the role of questions, the biology teachers focused on the students' lack of knowledge due to the fact that biological systems are not visible. They did not feel their students had useful prior knowledge to call upon, and therefore consider student questions as requests for direct information. Thus, they provide factual responses to student questions, and do not help them ponder and find answers for themselves. We see this being enacted in Marge's lesson on reproduction which looks closely at cell division and chromosomes:

Jim: ...I have a question. If you get 23 chromosomes from each parent, why do you look like one parent sometimes?

T: Ahh - you use dominance. Sometimes it masks another trait.

And later in the same lesson:

Stacy: When women go through menopause, they don't produce eggs. Do men have the same thing where they don't produce sperm?

T: Actually, men, I think, always continue t produce sperm. That's why you have someone like Cary Grant, a seventy year old father....

Gabe responds to student questions in much the same way, in the following lesson on reproduction:

T: A cell will have a nucleus with 12 chromosomes in the nucleus. So this is the mother cell with 12 chromosomes.... From this mother cell, how many daughter cells are produced and how many chromosomes in each daughter cell?...Tobi...how many daughter cells will exist?

Tobi: Two

It is then established that each daughter cell will contain 12 chromosomes. Shelby then raises a question:

Shelby: Since there are two daughter cells, wouldn't you think the 12 chromosomes would split up between them?

T: But it doesn't....One mother cell equals 12 chromosomes, two daughter cells equals 24 chromosomes total....

Both teachers interpret their students' questions as an indication of their desire to have an answer to their questions, rather than an opportunity to explore the ideas that led to them in the first place, or an opportunity to allow the students to formulate their own possible answers based on what they had already learned. The questions the teachers ask leave little room for students to formulate their own possible answers.

Thus, in the biology classes studied, students' ability to make connections and ask good questions seems to be related to the centrality of taxonomies in the structure of the course, and their notions that the taxonomies need to be learned in a part-to-whole manner, with new vocabulary assisting an understanding of how the system works. The taxonomies seem to be as much a system for reasoning as for labeling; the two seem intertwined. Therefore, students' ability to make connections and ask good questions is defined in terms of their ability to manipulate the particular concepts under study and to fit them into a larger classificatory system. However, underlying this is the teachers' sense the functions and systems being studied were generally new to the students (primarily invisible in daily life); they felt the students had few underlying concepts on which to build, and their major goal was to supply this base.

Physics

Teachers' concerns in physics were somewhat different, focusing primarily on students' ability to make observations about phenomena in nature, and using these observations to understand underlying principles of physics. Although physical principles are not observable, they underlie the ways in which things operate in the natural world, and thus natural phenomena become a central part of the lessons.

Connections. The physics teachers in the study felt that the understanding of patterns and relationships in nature is the goal of physics, and that making these sorts of connections is an integral part of learning to understand the principles of physics. Through observation of natural phenomena, they hoped their students would be able to make connections between and among the phenomena being observed and their concepts and properties. However, because the teachers often feel that the concepts are complex (e.g., "Friction is messy."), they treat them in a simplified manner, with smaller facts and observations connected to a generalized concept of the whole.

For instance, in Stan's unit on refraction, the class had first hand experiences with the ways in which light passes through various objects. First they established that the light ray bends when it hits the flat surface of the prism at an angle, but not when it hits it straight on. He began by making connections the next day:

T: Actually, we are going to take a look at this refraction business again, but today what I am going to do is address the concern I sensed all of you had, the question. I want to actually put together one of the continuing themes of the course, looking for patterns in numerical data. Which means we're going to have to get some numerical data and we're going to have to understand what the phenomenon is--refraction, this business of light-bending. And I want to address the concern that I sense you all have...that all that we have done with refraction has been qualitative. We've seen light bend when it passes from setting and one material to another, but we haven't measured how much it bends....We'll start doing that today with this little device here (the spectroscope). The first thing I would like you to do is just check again. There's something neat about this semicircular piece of glass when I aim light at it. And I would like us all to have a good idea of why I use a glass that shape. What's so great about it? Why does it allow us to see this refraction business more nicely? (and later on, after measuring)

And later said,

T: OK, now we can look for some kind of pattern between these angles....

Ken's course is set up to start with "big" things that can be easily observed, such as the motion of objects, and move to smaller things, such as to the motion of electrons and other subatomic particles. He said he hopes his students will see that "all the stuff interrelates....I tell them that the stuff you learned at the beginning comes back to haunt you later on."

Although Ken is more concerned than Stan about the naive misconceptions his students have about scientific concepts, both physics teachers feel that their students implicitly know about physics as a result of having spent their entire lifetimes observing natural phenomena in the world around them. Thus, their challenge is to help students connect and refine this everyday knowledge with theory in order to understand physical properties and phenomena--the nature of the outer world.

Questions. In a similar manner, the physics teachers in the study believed good student questions indicate a search for understanding of the principles in nature. The point Ken and Stan made over time was that they valued the accretion of a growing body of factual knowledge about physics, but that the students' ability to ask good questions about how things operate in nature and what their properties might be underlay such learning.

We can see Stan's attention to students' questions about the thickness of light beams during their unit on refraction. The students are engaged in measuring angles of refraction, and the following discussion is the result of a student's procedural question in which a property of light (the thickness of the beam) is being used to try to understand the angle of refraction.

Sam: How are we getting tenths if the light beam is like one unit thick?

T: That's a good question. How are you estimating?

Conway: Looking at the middle of the light beam.

T: (To Sam) You don't like that?

Sam: No, it's fine.

T: OK. Yes, Skeets.

Skeets: Wouldn't it be easier to do it by the edge, because the middle is easier to make a mistake?

T: Good point.

Conway: The edge isn't really, the middle is definitely better.

T: Why would you say it's better to use the middle?

Conway: Well, like, you have a clock with a hand. The edge is on twelve,

but it's not straight up and down. At twelve, it would be straight up and down and you would use the middle.

T: So, if it's a pointer of some sort, you'd use the middle of the pointer. But Skeets is saying if you're inconsistent about using one edge -

Skeets: Well, see, the thing is, in this pointer, it would be a wedge of the light beam, because it can't be a pointer if it keeps on going. It stops and you see the very end of the point. It goes right to the edge of the scale. The point is the edge of the light.

Conway: I think it doesn't make that much difference really.

Skeets: Neither does 7.5. (Oooo's from students in response to Skeets getting critical of Conway.)

T: Point well taken. Folks, let me tell you, I am impressed by this concern for accuracy. That's one of the things that comes very late for high school students, typically. Often there's very little concern for accuracy when, in fact, that can often be the difference between someone getting a good lab and someone getting a bad lab. It's just this very kind of concern for accuracy. You can take it too far, you can take it beyond the accuracy that this can give you. In other words, the best thing we can get for this set-up is the nearest tenth of a degree. If we are arguing over one-hundredths of a degree, that would be silly. I'm not sure it's silly to be arguing over a tenth of a degree. And I think you are making excellent points.

Stan could have immediately supplied the answer to Sam's initial question, "How are we getting tenths if the light beam is one unit thick?" Instead, he allows his students to make their own observations about the measuring procedure and to draw their own conclusions before commenting. In doing this he invites them to think like physicists and to probe issues related to degrees of accuracy. And he demonstrates that he values such thinking by complimenting them for pondering the issues.

Although Ken does not encourage students' questions in the way that Stan does, his students are free to ask them, and when they do he treats them as attempts to understand some principles of physics. He says he wants "the kids to find out, or at least to question things." He explained that, for example, he wants his students to ask questions about the hole over the ozone.

"It's over Antarctica. Why is the hole over Antarctica? Is it because penguins use an awful lot of deodorants? That doesn't make sense. Why would there be a hole there?" Here, Ken implies that good questions grow from observations the students make in nature and are moves toward more refined understandings of underlying principles of how things operate.

Overall, the physics teachers in the study displayed a continuing focus on the understand-

ings of physical properties their students were developing, always considering their students' connections and questions as evidence of their moves between what they have known or can see in the real world and the phenomena being studied.

American History

The teachers' focus in American History was on the cultural experience, on students' abilities to gain an understanding of the issues underlying the situations they studied, and to use these to interpret past, present, and future events and eventualities.

Connections. The American history teachers in the study focused on their students' ability to see topical relationships between and across people, events, and ideas. Both teachers indicated that they valued their students' ability to connect historical topics--to see cause and effect relationships and generalize about them, to connect current life experiences to events of the past, to relate one person, event, or idea to another. Thus, making connections, to the history teachers, involves searching for parallels and points of departure within and across cultures and eras. Similar to the physics teachers, they believed their students already had useful knowledge on which to draw in helping them understand the issues under study, and thus provided room for their students to make connections between the topics at hand and their own experiences.

Both teachers encouraged their students to work in groups and used this as an opportunity to help them try to find connections in underlying themes and issues across time and place. Laura provided prepared activity packets to guide her students to make such connections when they met in groups. Following is an example from a lesson on "Problems of the Cities in 1870-1900." In their group activity packet, the students were asked to find a connection between racism and ethnocentrism, and to link it to present day concerns. Three students work together, using the packet as a guide:

Tanya: Racism, ethnocentrism?

Gary: Is that...?

Tanya: That's when Americans, that's when country thinks

Gary: ...they are the best, yeah.

Tanya: Like America, Iraq.

Rick: Now, how would you solve racism in a city? It's still not solved in 1990.

Class: several talking at one time

Rick: Racial equality...you can instigate laws of (inaudible) equality, but you still have to worry about (inaudible) citizens and personal

feelings of those.

In a later lesson, the students are also expected to make connections--this time considering the situation in the United States today in regard to immigration, and comparing it to other countries. In the following discussion, the students are trying to make those connections:

Rick: Still, the United States is the number 1 place to immigrate.

Tanya: I agree.

Crystal: I disagree because of Japan.

Rick: I don't know, you got, Germany is together. That's going to be economically and militarily strong country. That wouldn't be a bad place to immigrate to. What else?

Later, in the packet, they are asked to connect the understandings they have gained from this discussion to the era and locus of study, problems of the cities, 1870 to 1900.

Both teachers also encouraged their students to make connections between their own personal experiences and the topic they were studying. Here, Kenny's students introduce relevant personal experiences during their class discussion on labor unions:

T: What are labor unions good for the society? What do you think?

Matt: In some aspect good...compensation.

Joseph: I'm not sure. I'm a member of a musicians' union. It doesn't have so much to offer.

T: What do unions try to offer?

When the students called upon their personal experiences, Kenny helped them connect the appropriate issues to the particular topic under discussion:

T: In most states, public employees can go on strike. Under the Taylor law there are very strong penalties in New York State.

Matt: Work to rule. What happened here in Midtown, when the teachers here were marching outside the school.

T: That's called picketing, some workers do that when they go on strike.

In general, the focus in the American history classes was on topical connections, making connections over time, place, and event in order to better understand the topic of the lesson and its broader implications.

Questions. The American history teachers felt that the ability to ask good questions was a critical feature of learning in their classes, because "students indicate their consideration and manipulation of the content by asking questions." Following is an example from Laura's class of ways in which students ponder historical topics across time. They are studying about immigration, and a student's question indicates his concern about governmental quotas on immigration:

Geoffrey: I just... they used to not be able to...I'm just wondering...they can't...Could the Chinese have the right, now?

T: Could the Congress make the laws now saying no Chinese could come in?

Geoffrey: Yes, I think if they wanted to.

T: Yes, if they wanted to they could. Do we have the right to decide which people can emigrate to the United States?

Geoffrey: More or less.

This student's question indicates that he is considering the issues beyond what has already been read and discussed. He knows that earlier in the century Congress passed a law restricting the number of Chinese who could enter this country, and wonders if the same legislation could be enacted today. Laura accepts Geoffrey's question as evidence that he is pondering an appropriate issue, helps him to tighten his question, and then goes on to answer it. Kenny also takes his students' questions as evidence that they are working through their understandings of the content. In the following example, although Kenny is about to make a link to a new topic, Crystal's question about anarchy, the topic they had previously been discussing, leads him to help the students understand anarchism more fully.

Students: Anarchists. (In response to a teacher question.)

T: Popular 19th century idea. Ultimate good...Was man good rather than evil?

Crystal: When you say anarchist, don't you think every one will kill each other?

T: What's your question for me?

Crystal: Isn't the idea of anarchism more idealistic?

T: Well, yes...

Thus, like the other teachers in the study, the American history teachers expect their students to make connections and to ask questions to further their understanding of cultural/historical topics. They expect their students to use their previous knowledge of life situations to help them understand the new content they are studying, and to make connections over time, place, and event. Because they expect to see growth in the students' understanding of the issues, they monitor students' responses and model ways of reasoning like historians.

American Literature

The American literature teachers were also concerned with their students' ability to make connections and ask good questions as ways to gain greater understanding of the human condition. Like the physics and American history teachers, they assumed that their students' cumulative lifetime experiences provide them with a good deal of relevant knowledge that can help them understand the coursework. However, the ultimate goal of the literature teachers seemed to be for their students to use life to understand texts as a way to then use texts to understand their own lives--and the human condition.

Connections. The American literature teachers valued their students' ability to make personal connections between what they read and their own lives. They also wanted their students to make connections between two or more works, with the expectation that their students would, in turn, use these connections to reflect on their own lives. For the American literature teachers we worked with, connections as a way of thinking expressed itself in two ways: a) in students' ability to relate ideas, situations, issues, and feelings to their own lives, and b) in their ability to arrive at interpretations of text and life based on those connections. Both literature teachers continually encouraged their students to make connections between their own experience and those they were reading. For example, in Linda's class, after reading Melville's Billy Budd, a character who receives unfair treatment, the students were asked to write about an incident in their own lives when they felt they were treated unfairly. One student not only wrote about the personal incident, but also tried to relate her story to Billy's:

> ...Like Billy, I was accused of forming a group, which he did not do, and I got punished for missing my curfew like Billy did get punished for killing the master at arms which was a reaction to what he was saying. My staying out late was a reaction to what my Mom said. So, in many ways, my situation was similar to Billy's situation.

This student received an A for her paper, and Linda also praised the connection her student made by writing "Great!" in the margin of her paper.

The teachers saw the reading of literature as a personal and sometimes idiosyncratic

experience, and tried to help their students make connections that were personally meaningful to them. For example, Terry tried to elicit his students' personal reactions to the assassination of JFK as described in Born on the 4th of July by Ron Kovic, but soon became sensitive to the fact that his students were too young to personally recall the assassination. They were reminded instead about the explosion of the Challenger:

Cameron: It was like, I mean, I can relate it to how I felt when the space shuttle, the Challenger, blew up. I was in school when I watched it, and I felt pretty bad, but not that many people in the class were taking it that seriously.

T: How many of you saw the shuttle explode...?

The next day he opened the discussion by returning to Cameron's connection.

T: Yesterday Cameron brought up the issue of the Challenger, and we used it for a couple of minutes. It was a good point, and I'd like to take it one step further.

He then asked the students to recall and jot down some of the emotions they felt when the space shuttle exploded. He also elicited some language from Kovics' piece that the students felt described the author's emotions. The students discussed some of the emotions they felt and compared them to the emotions Kovics had expressed. During the discussion, Terry was overt about the fact that their personal experiences can help them understand the text better--even if they haven't experienced the particular situation:

T: OK. What I'm trying to bring out here is that I kind of assumed that you understood that Kovics' reaction, but what Cameron brought out is that you're much closer to the Challenger event. You can connect to this, you can relate to it. That's the kind of response to literature that should happen in you. The literature makes you say," Yeh, I can connect to that. I may not have been there, but I can understand this." What I want you to see is that you have a basis for understanding this.

Terry also shows his students that he values literary connections. The following comment was made after completing the Kovics book, by way of introducing The Red Badge of Courage.

T: ...Think about what Kovics' response might have been had he seen Platoon instead of John Wayne movies. Tomorrow, I'll give you Red Badge of Courage, and we'll read about four pages that are similar to what we read in Kovics' book, and we'll see what you make of it.

In doing this, Terry ends his unit on Born on the Fourth of July not only giving the students

something more to think about, but also by scaffolding their ways to make connections between literary works. That one is a modern piece and the other from an earlier period in history lends substance to Terry's claim in the follow-up interview that one of his responsibilities as a literature teacher is to "help students make the connections between the value systems of their forefathers and the value issues of today."

Questions. The American literature teachers regarded questions as an indication that students are trying to personally relate to what they are reading. Similar to their interest in connections, their primary concern was with the use of questions to refine their students' understandings of human experience, theirs and others'. For example, Terry responds to Robin's question in the following manner, and Etta joins the discussion to open it up for further scrutiny:

Heather: Is that really happiness, or is it just relief that you weren't the one who died?

T: Happiness might not be the right word. We're trying to deal with Jim's reaction. It's a wonderful, honest reaction....

Etta: I was confused when I saw it. I didn't understand it.

Overall, the literature teachers assumed that essential meaning was in their students, based on the life experiences they had engaged in or witnessed, and that the literature lesson involved using these in relation to the text and other texts in order to gain more complex understandings not only of the piece being read, but of life in general.

Making Connections and Asking Questions: A Look Across Disciplines

Connections: General Comments. In the preceding section, we have discussed ways in which the biology, physics, American history, and American literature teachers in this study value the ability of their students to make connections. However, there are differences in the kinds of connections they value. The biology teachers value the students' ability to build taxonomies in order to understand how biological systems (which are not openly visible for students to inspect) work; the physics teachers value the ability to see physics in action and to use these experiences to understand physical patterns and properties in nature; the history teachers value the ability to see connections within and across situations, people, and time; and the teachers of literature value the personal connection, leading to enhanced understanding of the piece being read and of the self as well as the connections across texts.

Although the notions of connections in history and literature seem similar at first glance, we have seen that they are enacted in different ways in the classroom, with greater focus on objective content in history and on subjective responses to text and life in literature. For example, the history teachers we studied want their students to be able to draw parallels between past and present events, believing such connections can help guide present understandings and

actions. Although such connections focus on human situations and therefore seem to involve personal links such as those valued by the literature teachers, they are quite different. In history, the focus is on connecting personal experience and the topic at hand in order to better understand the present content of study; the focus of the personal experience is on the content--the information to be linked, while in literature the students' connections of their general understanding of feelings, motives, or behaviors are the focus, leading to a better understanding of human elements in text or in life. In one, the main focus of the connection is about general human feeling and behavior in the other, it is about a specific subject matter content.

Questions: General Comments. Although all the teachers valued student questions, considering them an important part of the process of learning, their notions of the particular role the questions play in students' thinking seem to be affected at least as much by the particular discipline as by their approaches to teaching. More so, the ways in which the students' questions were treated seem to be implicitly related to the kinds of knowledge the teachers think the students have (and need) in order to be able to approach the answer themselves. The biology teachers seemed most certain that their students had little prior knowledge about the topics being studied. To them, familiarity with the technical labels identifying aspects of the organism or system being studied, and the role of those parts within the larger taxonomy, are essential to understanding. This is certainly related to the fact that the high school course of study in biology contains some 500 vocabulary terms the teachers feel compelled to "cover. However, they (and as far as we can surmise, their field in general) believe students won't be able to understand more until they have learned the basic language and concepts. Because these are unknown to the student, the purpose for questions is to gain the needed information, and the ability to answer the questions lies with the teacher who knows these basics. In contrast, the physics teachers expect that the students will have had some experiences with natural phenomena, and assume this knowledge will be useful for answering questions in class. Thus, even when the students' questions seem highly technical, the teachers assume the students will find some way to explore the problem. Though students in both physics and biology often asked questions about the unknown (What's a proton made of? What does a prostate gland do?), they were treated in different ways. In biology, the focus was on learning the label or definition, while in physics it was in reasoning about the problem.

The similarity between the valued questions in biology and physics was that both sought information--whether supplied by the teacher or reasoned about by the students. So too in history, where there was particular content to be questioned and considered across people, places, eras, and situations.

However, the literature teachers' notions of good questions were qualitatively different from the other teachers'. Good questions in literature class were more exploratory musings than information-seeking in intent, both on the part of the student and (often) on the part of the teacher. They were closer to what Langer (1990, 1991) calls exploring horizons of possibilities, where the shape of the piece and the students' notions of what it is about are fluid--flexing and shifting as possibilities are pondered and their implications imagined.

These analyses suggested to us that it may be simplistic to assume that students in these

classes are not learning to reason in their academic coursework. From our in-depth study of the eight teachers (see final report for additional analyses and discussion), we came away feeling that some reasoning seems to be taught. There appear to be sensible and purposeful subject specific ways of reasoning embedded in the intentions underlying the activities and learning goals of the coursework, but never identified or singled out as essential evidence of good thinking. Because they are implicit, the teachers were unable to "flag" them at will and mark them for their students as important elements of disciplinary learning.

How Teachers Support Student Thinking: Examining Discipline-Specific Pedagogical Routines

All the teachers we studied had a generalized knowledge about reasoning reflected in a common vocabulary which enabled them to discuss their professional goals and instructional activities in broad terms; but, as we have already seen, this general understanding did not capture the differing kinds of thinking they actually valued and supported in their classrooms. The teachers imbued these general concepts with more particular meanings, meanings that were shaped by their sense of modes of thought appropriate to their particular disciplines. These notions of discipline-specific ways of knowing were tacit, systematically recurring within the classrooms, but unmarked as principles or guides the teachers were following. It is at this level of re-interpretation of general pedagogical concepts in discipline--specific ways that we need to seek evidence for reasoning within each discipline.

Commonalities across the disciplines. Across disciplines, there were some commonalities in the ways teachers tried to shape students' thinking as the lessons developed. These commonalities included finding common ground before discussion of new concepts, clarifying students' understanding, and focusing attention on significant details.

For example, at the beginning of almost all lessons, there was a "search for common ground," similar to what Stubbs (1976) calls "keeping in touch." This search sometimes also occurred at other points in the lesson, marking a change in topic or the attempt to help the students make links with a difficult concept introduced during the lesson. Although at one level this seems to call on factual recall, in the social context of the class, it always served as a way to provide the students with an opportunity to become aware of their own ideas, hear what others had to say, and relate them to the topic at hand--in preparation for dealing with more complex issues. It served an interactive surveying, stock-taking, and pooling function, inviting the students to develop initial envisionments (Langer 1990, 1992) from which to build new learnings. For example, Gabe (biology) called for common ground in this way, when a student asked a question he thought the other students might not understand.

Carol: Do hydras have stinging tentacles?

T: Yes, however, were any of you viciously stung a couple of months ago by the hydras?

Eric: No, how come?

Stan began a physics lesson at the beginning of a new unit with a search for common ground, in an attempt to help his students collectively brainstorm about force. He explained to his students that the key idea they were going to focus on in the new lesson was force, and opened the discussion by asking them what the idea of force meant to them. And, when Terry wanted his students to make some difficult comparisons between two works his students had just read, he too called for common ground:

T: On the board is what we want to think about ("The Emerson piece leads to images, implications, and outcomes that are different from Thanatopsis."). Do you agree or disagree? What do you think?

In each case, the teachers used a public forum to invite the students' immediate responses, as a way for them to become aware of, and begin to select and refine related prior knowledge.

At other points in their lessons, all of the teachers were concerned with helping students clarify their understandings. For example, in Kenny's American history class, he tried to help his students clarify their understandings of carpetbaggers and how people felt about them in the past in comparison to today:

T: OK. These negative people, carpetbagger is a negative word today, were they nasty people?

Linda: Some might have good intentions - businessmen.

T: What do you mean?

Linda: (not audible)

T: Do you see that positively or negatively?

Stan (physics) encouraged a student to clarify his thoughts in the following:

T: ...How do the amounts compare, Ben?

Ben: They're equal.

T: Equal. Why do you say that?

In these exchanges, the teachers were helping students move beyond their initial thoughts and responses, to become aware of and clarify more specific understandings.

Another set of techniques used at least some of the time by all of the teachers focused students' attention on details of the subject matter, asking them to recall or locate information. These moves generally focused on particular facts and terminology rather than broader understandings, and were sometimes used simply as a check on whether students had done their reading or were paying attention in class. Following are brief examples from Linda's (American literature), Ken's (physics), Marge's (biology), and Kenny's (American history) classes.

American Literature:

T: Pearl associates Chillingsworth with who?

Gail: The devil.

T: What does he say?

Physics:

T: Now, what causes this? (pointing at diagram)

Students: Mirror reflection.

T: Yes, that's reflection, believe it or not. Yes it is.

Biology:

T: Go from what to what?

Joe: The testes to the urethra

T: the testes to the urethra--and that is the tube the sperm gets shot through. In females what's the tube?

American History:

T: What did they call those White southerners?

Mark: Scalawags.

T: OK. What's the pejorative word?

Kim: Carpetbaggers.

In each of these cases, the teacher was monitoring students' recall of significant details and focusing students' attention on them. Thus certain instructional moves were orchestrated by the

teachers in ways that guided students toward one or another type of thinking about the material. These moves functioned as a kind of instructional scaffolding that was independent of teachers' disciplinary frames of reference, being guided primarily by the teachers' general pedagogical approach.

Disciplinary Patterns of Language and Thought

Although the teachers' awareness of specific ways of thinking appropriate to their discipline was tacit, there were patterns of thought that were systematically modeled and sought within each discipline. Across the disciplines we studied, embedded in the teachers' lessons were three different concerns that dominated different lesson segments, and which took different shapes in each discipline: orienting students' attention, refining their understanding, and helping them select appropriate evidence. These concerns guided the teachers in scaffolding disciplinary ways of thinking. (For a discussion of scaffolding ways to discuss and ways to think, see Langer, 1991.) As they focused on these three concerns, the teachers guided students' understanding of the particular nature of the discipline-specific content and of the appropriate ways to think about it.

Biology

Orienting Attention in Biology. Reflecting their overarching sense of what matters most in the study of biology, the biology teachers in this study used guiding questions to help their students focus on the features of biology they considered critical: in this case to focus on biological functions, their labels, and their place within a larger system. We see this in Marge's unit on sexual reproduction:

T: They (the tubes) go from what to what?

Joe: The testes to the urethra.

T: The testes to the urethra. And that is the tube the sperm gets shot through. In females, what's the tube?

Jim: Fallopian.

T: And what's the common name?

Jim: Oviducts.

T: And we have how many?

Jim: Two.

T: One from each _____?

Jim: Ovary.

Through this close modeling, the teachers helped their students determine what to attend to--what counts as knowing--in their classes.

Refining Understanding in Biology. Also reflecting their overall emphases, the biology teachers helped the students to refine their understandings of biological terms and functions as well as their place within the larger system of which they were a part by encouraging them to review and repeat the terms and patterns. In Gabe's class, it looked like this:

T: Do you understand what he said?

Jo-Jo: Yes.

T: So, what are you going to draw next to the arrow?

Jo-Jo: (inaudible, struggling to get out answer)

T: Who regenerates the most?

Jo-Jo: Complex.

T: No, you're not looking at trends. Kevin, who is going to regenerate the most?

Kevin: The first one.

T: Number one, next to number one, which is the tip of the arrow, the greatest regeneration. Number one is the greatest regeneration. Number five is _____?

Kevin: Least.

Thus, refinement, in the biology classes we studied, frequently took the form of explicit review, often using unmarked diagrams to be filled in or charts to be developed by the students.

Selecting Evidence in Biology. Because the focus in biology was strongly on systems, the teachers asked the students to provide evidence of this knowledge by using proper labels for the parts, and relating them to the system. In discussion, they often were asked how the parts functioned, but when working alone, they were more often expected to place the parts within the system. Thus, giving evidence of learning in biology involved the ability to generate the appropriate label for a particular function within the system being studied, and sometimes the

ability to discuss the ways in which the systems functioned.

Following is an example from Marge's class. She helps them find evidence that erection can occur in males without the ejaculation of sperm. Notice that she reviews the meanings of terms as well as providing an example:

Gerry: Can you have an erection without ejaculation?

T: Yeah, didn't we talk about little kids going in the water all the time?

Leslie: Yeah, I've seen them (get an erection).

T: Erection is the penis becoming firm, straight. Ejaculation is the release of sperm.

(later in discussion)

T: If you have little brothers or if you babysit, it is real common if they go into cold water they get an erection.

Jim: They can't control it.

T: The nervous system, it's a real sensitive area and the cold causes an erection. It has nothing to do with sex. If you have an infant and you put something cold, water, on him when you are changing a diaper, oops, it happens.

Class: (laughter)

T: The kid is not having sexual fantasies. This will happen. You have brothers, you will have kids someday. It's real common. It's just something that happens to a little boy. OK, have we covered everything? Oh, why does the penis have to do this?

Thus, we see that in the biology classes we observed, the pattern of instruction oriented students' attention, refined their understandings, and asked them to select evidence in ways that would systematically lead them toward the kinds of knowledge that their teachers valued as important in biology.

Physics

Orienting Attention in Physics. The physics teachers apprenticed students in ways to think by guiding them to carefully observe and investigate the natural phenomena they were

studying. The teachers oriented students' attention primarily through close guidance about what to think about. Ken guides Sam in what to attend to the following:

T: ....Lean (the water-filled beaker) so your coin is on the edge now. Take a look at all those images that are in there now. You've got a really nice big one, nice reflection on the bottom....Notice that your coin looks "bended" in the back. Yes? OK? also, take a look at it through the side surface, so you're looking straight through the thing. Very easy to see a nice reflection on the bottom now.

Sam: I see six coins.

T: Oh, yeah, you can see a lot of things this way.

While Ken helped Sam orient his attention to real-world phenomena during a class activity in the previous example, the physics teachers also carefully guided students' attention during class interaction as well. Stan's lesson is an example:

Joe: Is there any difference between individual atoms, like neutrons?

T: One neutron and the next are totally indistinguish- able.

Joe: What about the stuff like neutrons and protons in the same atom? Any difference in areas inside?

T: Oh, ahhh, you've got me. I know that neutrons and protons have lots of characteristics that make them different. Are they made up of the same stuff, just different sizes? No. But there are some similarities. In other words, if you break protons apart and neutrons apart, you'd find some similarities in their components, some of the same constituents....

Thus, in both experiments and discussions, the physics teachers helped the students learn to closely observe and investigate--modeling appropriate ways of thinking in physics.

Refining Understandings in Physics. The undergirding goal of the physics teachers was to help their students integrate the physicist's ways of describing physical phenomena with their own. Thus, the teachers served as mediators between students' understandings and accepted understandings, trying to refine students' understandings toward general scientific interpretations of reality. Sometimes the teachers actively shaped the students' thoughts to match physicists' constructions; at other times the teachers would explain how a physicist would depict the phenomenon they were discussing. In the following example, during a unit on electrostatics, Stan shapes his students' observations, guiding them to link their observations to explanations of phenomena they had already studied:

T: It would become negative. If there's a transfer of negative charge from the comb to the ball, the ball would become negative. And if that happened, what would the ball do to the comb?

Joelle: Repel.

T: Repel. And then see, it's still attracted (He has not allowed the comb to touch the ball). But let me show you what happens when they touch. (Allows the comb and ball to touch and then they immediately repel each other.) OK, now what do they do?

Jacob: Repel.

T: Repel pretty well. So, what happens when they touch?

Jacob: Transfer of electrons.

T: Transfer of electrons from the comb to the ball. Now they are <u>both</u> negative, and they repel quite nicely. So that happens when they can touch, but not when they don't. Let me show you (draws on chalkboard...).

Thus, the physics teachers helped their students refine their interpretations in discipline-appropriate ways.

<u>Selecting Evidence in Physics.</u> The physics teachers made it quite clear to their students that the provision of evidence in their classes required them to make direct links between the phenomena they had observed (or discussed) and the principles of physics they had learned (or were learning). Acceptance of a principle or reaching such an understanding was supposed to be based on the ability to replicate the evidence a number of times. We see this in Stan's class, later in the unit on electrostatics. He was helping his students group materials by the common ways they reacted to other materials:

T: ...Repel, but there was contact. We did it without touching yesterday. We found that white plastic rubbed with felt repelled clear plastic rubbed with denim....

T: These are two kinds of things we can learn in class. We're learning this today, on a specific day, so there's number one, specific things. Secondly, there are things that carry over through the whole course. I'm interested in looking for patterns, and trying to figure out how something works. So, what I want to do today is to try to figure out how something works. And the way that you know that you've done that is that you're able to make good predictions....So, let's try this out. Let's try to build some theories, look for patterns, build a hypothesis and the way to do that is to muck

around with this stuff....(Reviews the data they have already discovered concerning how the three piles of things attract, repel., etc.) Can you build a, do you see a pattern here? Can you make a general statement that says, "Whenever blah, blah, blah, blah, then blah, blah, blah? Conway, what would it be?

Conway: Like objects repel. Does that fit our data so far?

Students: Yes.

T: Three for three. (Reviews the three different ideas again.) Can you build a conclusion?

Students: Opposites attract.

T: Now start testing our hypotheses, and do so by making predictions. How compare?

Skeets: It's different.

T: How do you think it's do you think this is going to behave with these two materials?

Some Students: Attract.

T: Agree?

Skeets: Attract the clear plastic and repel the white vinyl.

T: Attract the clear and repel the white, but some are saying attract both, which is fine. Folks, I don't have a problem with dissention. We don't all have to think the same thing yet, (whispering), but we will. Teri, why did you say it was going to attract both of them?

Teri: Well, because based on our conclusions, they're different objects and we said they would attract and they're different.

T: So, now I put it to Skeets and Irving. Didn't you say attract one and repel the other?

Irving: I think it will repel the white and attract the clear.

T: Can you tell me why?

Irving: (No response, shrugs)

T: So far we have three competing models. So far I've heard three things: like things repel, opposites attract, and things aren't really that different. Any other thoughts? Sam?

Sam: Does it have something to do with, like light goes through it?

T: Jacob?

Jacob: I don't think the cloth makes that much difference.

T: OK, we can test that. (This leads to a search for evidence during a series of experiments with a variety of materials.)

Thus, the physics teachers in this study asked their students to select evidence for their explanations for physical phenomena by making relevant connections between aspects of the specific occurrences they had witnessed and scientific principles that could account for them.

American History

Orienting Attention in American History. In comparison, the American history teachers in this study oriented their students toward contextualizing the historical information they were studying. First they narrowed the content they were focusing on, highlighted it, and then helped the students consider it from a human/cultural perspective. Thus, the teachers oriented their students' attention not only to the specific material being studied, but toward forming their own contextualized understandings and explanations. Both history teachers guided their students to explore and consider the implications or outcomes of cultural and social aspects of the material they were studying, as Laura does in the following segment:

T: What was missing? In what way was his (reasoning) faulty? If poverty was the effect, what was the cause?

Molly: Immigrants.

Refining Understandings in American History. Since the focus in the history classes was on contextualizing the content the students were studying, the teachers sought to refine students' understandings by asking questions that invited them to view the event or situation in more complex ways. For example, the teachers would ask their students to determine motivations and biases, or to consider an explanatory argument from the vantage point of specific historical contexts (e.g., a particular era or culture) or perspectives (e.g., their own, an author's, or a particular political, economic, or gender-related view). We see this as Laura's class discussion continues:

Daniel: If we get rid of immigrants, we get rid of poverty.

T: Anything else? Any other way you thought that his reasoning might not be correct?

Rosa: You can change numbers.

T: I..I wouldn't say he was specifically lying about the numbers, but, often when numbers are used they can be manipulated.

Mike: Audience...

T: All right, what do we know about the audience? What do we know about the audience who is going to receive this speech?

Selecting Evidence in American History. Because the goal in the history classes was to help the students gain the ability to understand and explain historical events and situations from the perspective of cultures and contexts, learning to select evidence involved explaining and defending particular interpretations. To this end, the teachers guided their students in ways to provide the facts, as well as the students' explanations and interpretations--through similarities and contrasts, by explaining connections across time, cultures, and situations. For example, in Laura's unit on immigration, the class is guided to gain evidence for their disagreement with an author's view, based on some reports, that immigrants caused unemployment:

T: ...OK, the reports (the students have already agreed) are reinforcing a bias, prejudices....And so, if you say that 39.4% of, look at that, you may view that as a very high number or you....Any other faults you can find in his reasoning?

Gary: In "Relevant Information," he says that most of the crimes are committed by adult males, and in his statistics he includes men, families, and children.

T: All right, when in any of these numbers, remember it says in "Relevant Information," that mostly males, and he is talking mostly male population carrying it into total population .... Also, lacking in his argument are the reasons for the poverty. What's the reason that the immigrants are poor?....

Rick: Low wages,

T: Yes, they make low wages when they come here. Well, why do they make such low wages?

Tanya: They don't really know any better....

T: ....So he makes this, when you read that you think just because they are

immigrants from Southern and Eastern Europe they are poor, they must be poor without taking even into consideration any of the things that might be happening in America. OK, so when you read that, you automatically think, well, they are causing poverty...pretty far out assumptions.

Gary: It's not true, there are no facts in his argument.

T: All right, there is absolutely nothing in his argument to suggest that the crime rate in those countries is high. OK?

(later, Laura helps them think about other evidence she thinks is relevant)

T: Once again, what we are lacking is the reasons for the crimes. Maybe they didn't have enough food to eat. Questions?....

T: Did the immigrants cause higher employment?....

Similarly, during the lessons in his class, Kenny frequently asks his students to look for evidence and at the same time weigh that evidence. When they make assertions, he requests evidence by saying, "You can back it up with what kind of evidence?"

Literature

Orienting Attention in Literature. The literature teachers in the present study invited their students to become literary thinkers by orienting them toward examining, sharing, and expanding their personal interpretations. This was often accomplished by asking open-ended questions that tapped the students' responses. For example, Terry asked his students such questions as,

T: What do you think?

T: What do you mean?

T: Do you mean ....?

T: What are we to do with this?

Linda's questions looked like this:

T: Why don't you think Hawthorne says this?

T: Why does Hawthorne leave it out?

T: How many people thought the same as Raymond?

In Terry's class, the students' responses were often treated as more important than the text.

Refining Understanding in Literature. Refining understandings in the literature classes involved having students share their interpretations with class members, exploring and elaborating them, and considering possible implications. By asking questions, Terry guides his students to refine their understandings:

T: Do you agree or disagree (with the statement "The Emerson piece leads to images, implications, and outcomes that are different from Thanatopsis")? What do you think?

T: What about the images?

Marie: The earth is a tomb. That's how you see it when it's dead.

T: What do you mean?

Marie: Nature is death.

T: Anyone agree?

By inviting other students to counter with their own perspectives, Linda also helped class members refine and develop their own interpretations (e.g., "How many people thought the same as Raymond?" "Anyone want to add to that?" "Anyone agree?"). Both literature teachers systematically help their students learn to refine their understandings by sharing ideas with the class, elaborating them, and drawing implications.

Selecting Evidence in Literature. By use of questions, the literature teachers frequently guided their students to use their texts, their previous class discussions, their personal knowledge and experiences, and other literature as sources of evidence for their responses. In Linda's class the students were led to locate evidence for accepted interpretations, while in Terry's class they were led to think through the reasonableness of the evidence in interaction with their own developing understandings.

Terry asks his students to provide their own evidence, but guides them in doing so, providing them room to question and seek evidence for various lines of thought:

Sal: He can see what's going on but he's transparent so no one can see him, so he can't affect what happens.

T: Where does that come from in your thinking?

Jen: He's just

T: It comes back to what we were talking about--the unity.

Eddie: I don't understand what you just did, the connection you made, Mr. X (referring to the teacher).

Jen: It's the reason for the unity, that he is able to see it.

Helen: It doesn't mean that he sees all. It just means his vision is clear.

Linda, on the other hand, guides her students back to the text to find evidence, moving them from the text toward the interpretation she wants them to understand. She also expects her students to provide information from the text as evidence for their interpretations. For example, in a unit that included Thoreau, Stanton, Truth, Douglas, and Harper pieces, Linda asked her students to write an essay on the authors' beliefs, with evidence as stated in the texts. Sheri offers these examples in support of Elizabeth Cady Stanton and Sojourner Truth's beliefs that women should be treated equally to men:

Sheri: ...women should be able to have a say in the laws that they must follow and women should get the children after a divorce.

And she offers the following examples from the Sojourner Truth piece as evidence for her claim.

Sheri: Some of these men say that a woman should be treated delicately for they are fragile, but Truth says that she is a woman and has never really been treated that way. [The men] also say that since Christ was a man it is only natural that men have more rights than women. Truth's reply to this is that Christ had to have a mother and she was a woman.

What Linda was looking for, and what she got, was evidence that her students were able to use the text to support their understandings.

Thus, the literature teachers guided their students in how to select evidence to back up their assertions by using the text and their previous discussions, as well as other related knowledge from life and other literature. In both teachers' classrooms, all these sources of knowledge were sanctioned some of the time, but Linda sought far more textual and Terry far more student-based evidence.

Disciplinary Foci

Thus, as depicted in Table 2, the biology teachers helped their students examine the invisible world of living systems and functions, the physics teachers helped their students examine the outer world (their observations of physical phenomena), the history teachers helped

their students examine the social world (contextual information), and the literature teachers helped their students examine their inner worlds (their responses to and interpretations of literature).

Table 2
Disciplinary Foci

Biology: Examining Invisible Worlds

Orienting Attention
isolating critical features of system to be studied and focusing on their labels and functions

Refining Understandings
connecting names and explaining functions within the larger system of which they are a part

Selecting Evidence
replicating labels and functions in accordance with accepted systems of classification and description

Physics: Examining Outer Worlds

Orienting Attention
flagging and observing aspects of natural phenomena under investigation

Refining Understandings
examining possible explanations based on related scientific knowledge

Selecting Evidence
making direct links between observed phenomena and accepted principles of physics

American History: Examining Social Worlds

Orienting Attention
identifying and contextualizing particular historical content

Refining Understandings
exploring content from multiple social and cultural perspectives

Selecting Evidence
explaining interpretations by example, through similarities and contrasts

American Literature: Examining Inner Worlds

Orienting Attention
identifying personal response or interpretation to be explored

Refining Understandings
developing interpretations by exploring multiple perspectives and considering possible implications

Selecting Evidence
using text, previous discussions, personal knowledge, and experiences to explain interpretation

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What labels and taxonomies were to biology, observations were to physics, social contextualization was to history, and personal interpretations were to literature in the particular courses and teachers we studied. In helping their students learn how the various biological systems worked, the teachers guided their students to remember the parts of systems, how they functioned, and the technical terminology they felt was prerequisite to talking and thinking about them. In helping their students understand their observations, the physics teachers guided their students to link particular observations to accepted principles. In helping their students learn to interpret and gain insights from historical events and situations, the American history teachers guided their students to explore the content from a variety of social perspectives. And in helping their students understand and interpret literature, the English teachers helped their students share, elaborate, and reflect on the personal and the possible. While all teachers in all the classes we studied were concerned with orienting students' attention, refining their understandings, and helping them select appropriate evidence, in conveying their subject-specific ways of reasoning to their students, they guided their students to think in ways that were particular to their discipline.

Discussion

The purpose of this study was to examine ways of knowing and reasoning in academic coursework, and of the ways in which teachers' general goals are realized in their subject-specific pedagogical strategies. In an earlier study, we found that although teachers talked about the discipline-specific goals they saw for their field, the closer to the daily activities of the student, the more the focus seemed to turn to facts, to the exclusion of ways to a think about them. However, the earlier study was limited to review of the scholarly and pedagogical literature and to teacher interview data which needed to be augmented by classroom observation. The present

study provides the next step, linking the initial studies of teacher knowledge to studies of teachers talking with teachers as well as in-depth observations of classroom practices.

The findings of this study suggest that our earlier findings were not wrong, but limited; that it is insufficient to conclude that students are not learning about ways to think about the facts that are part of their coursework simply because teachers lack the vocabulary to talk about those goals. Instead, this study suggests the following:

1. Reasoning is being taught and learned in academic classes similar to those in this study.

2. Such reasoning is subject-specific and embedded in the pragmatic routines of subject-driven lessons.

3. The specifications of such reasoning are implicit; not a recognized part of a teacher's knowledge or language base, and therefore unavailable for overt use in lesson planning or as strategic knowledge that can be shared with or taught to students.

4. The kind of discipline-specific reasoning described in these findings may or may not be sufficient for successful participation in disciplinary learning or in meeting the literate thinking goals of our society.

5. Certain types of pedagogical approaches or styles may inhibit or support such discipline-appropriate thinking.

6. Additional studies involving more teachers are needed before we can comfortably make explicit suggestions for the recasting of instruction along discipline-specific lines.

7. The categories identified in this report, representing disciplinary ways of thinking in each of the four disciplines studied, may provide a useful place to start an investigation leading toward productive instructional reform.

In addition, findings suggest that there is a general pedagogical vocabulary that teachers use to indicate their concerns about student thinking. By their very nature, these general terms mask underlying differences in the kinds of thinking they are meant to represent. What counts as thinking seems to be deeply related to the particular discipline and to the underlying ways of thinking embedded in it. However, these disciplinary concerns seem to compete with the more general pedagogical notions of reasoning that are part of the field of education. Thus, curriculum goals, assessment instruments, and instructional approaches that focus on general reasoning abilities across the disciplines may fail to teach or test the particular skills that are most useful in the thinking activities of the actual disciplines. And this may, in part, be a shortcoming of the recent critical thinking reform movement in American education.

Additional research is needed. The teachers in this study were a select group who were

interested in professional change, and in providing rich reasoning contexts for their students. Even they, however, were relying on tacit knowledge. Thus, teachers not overtly trying to create such thinking-rich classrooms might look much different in the reasoning behaviors they provoke in their students. In any case, the discipline-specific descriptions and categories reported here have the potential to provide the various fields with ways to reflect on the kinds of language and thought that are valued and on the pedagogical routines that support rich and thoughtful reasoning in particular academic subjects. Such directions contribute to a growing but still underconceptualized movement that wishes to place students' thinking and reasoning at the center of educational reform, and reinforces the underlying goals of strengthening our understanding of, and commitment to, a rigorous, academic, and above all more thoughtful education for all.

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